

THE PERFORMANCE OF LOCALLY PRODUCED XANTHAN GUM IN DRILLING MUD

I.ISMAIL¹,P.S. LIM²

ABSTRACT

Xanthan gum is one of the important mud additives nowadays which acts as viscosifier. Currently, Malaysia oilfields mainly are using imported xanthan gum from China, which is very expensive due to towering demand. Therefore, this research project focused on the performance of locally produced xanthan gum in drilling fluid. Laboratory works conducted were mainly on the rheological properties, API fluid-loss, and the pyruvate content test. The experimental results revealed that the locally produced xanthan gum could not match the performance of Flowzan.

Key Words : Drilling mud, Flowzan, oilwell drilling, viscosifier, xanthan gum

1.0 INTRODUCTION

Xanthan gum is an extracellular polysaccharide produced by fermentation of the bacterium *xanthomonas campestris* [1]. It has high viscosity ability, coupled with excellent stability under high temperature and varied pH with unique shear thinning properties that enable it to be used as a viscosifier in the oil field for drilling, drill-in, and completion fluids [2]. In this paper, we explored how the locally produced xanthan gum could be used as commercially as viscosifier and temporary fluid loss control in drilling operations.

Locally produced xanthan gums that had used in this research study were produced at different temperatures of heat treatment, namely 90°C (Sample 1), 100°C (Sample 2), 110°C (Sample 3), and 130°C (Sample 4). These samples could be differentiated through their color and outlooks. All these samples had gone through the rheological properties and fluid loss control tests at both before and after hot roll temperatures.

The pyruvate content of these samples was also studied using the High Performance Liquid Chromatography (HPLC). Through the pyruvate content of these samples, we could determine the concentration of xanthan cells in the samples as well. This is one of the main factors that influence the viscosity loss of locally produced xanthan at high temperatures.

The rheological performance of best-performed locally produced xanthan gum was compared with commercial xanthan, Flowzan. The water-based mud system with xanthan gum as an additive had been tested for its fluid loss characteristic and compared with Flowzan and corn starch. Those experiments were carried out over a wide range of temperatures 23.9 to 101.7°C (75 to 215°F), using the same concentration of mud system. In general, temperature affects the fluids behavior which in turn affects their viscosity [3,4].

¹ Department of Petroleum Engineering, Faculty of Chemical and Natural Resources Engineering, 81310 UTM Skudai, Johor, Malaysia

² Halliburton Energy Services (M) Sdn. Bhd., 11th Floor, Menara Tan & Tan, 207, Jalan TUN Razak, 50400 Kuala Lumpur, Malaysia

Correspondence to : Assoc. Prof. Issham Ismail (issam@fkkksa.utm.my)

2.0 MATERIALS AND METHOD

This section comprises drilling mud preparation, rheological properties test, moisture content test, and shear-thinning determination.

2.1 Drilling Mud Preparation

The basic water-based mud was used in this research. This formulation was based on the QA/QC standard [5] of KMC. The formulation of mud system was as follows:

Materials	Quantity
Water	315 ml
Soda ash	0.5 gram
Caustic soda	0.2 gram
Bentonite	8 gram
Barite	130 gram
Local xanthan gum/Flowzan/corn starch	1.89 gram

The xanthan gum, Flowzan, and corn starch were added separately in different muds which allowed the performance of certain additives to be identified and compared accurately.

2.2 Rheological Properties Test

The rheological properties (i.e., average viscosity, plastic viscosity, yield point, gel strength, pH, and 6 rpm reading) of the mud were conducted using rheometer. The fluid loss test was conducted using filter press by taking the readings at the end of 30 minutes. Those tests have been conducted at ambient temperature as well as after hot-rolling for 1 hour at 215°C in an oven. All the methods were conducted as per the API standards namely the API RP 13B [6] and API 13I [7]. Besides, pyruvate content and moisture content tests were conducted as well to investigate the performance of local xanthan gums.

In the pyruvate content test procedures, xanthan gum samples at a concentration of 0.1% w/v were hydrolyzed in 1N HCL at 80°C for 24 hours. Then, 10 ml H₂O was added to the hydrolyzed prior to the extraction with CH₃CO₂C₂H₅. The procedure was repeated three times. The organic phase was removed through evaporation and the residue was diluted in water. Pyruvate was determined using HPLC. The samples were assayed using a SEPARON SGX C18 column and an UV detector at 210 nm. A 0.2 M H₃PO₄ solution was used as eluent at a flow rate of 0.8 ml/min. An aliquot of 5 µl was injected on the SEPARON column, while procedure was performed at ambient temperature and repeated two times [8]. The concentration of xanthan cells was calculated as follows:

$$\text{Concentration}_{\text{unknown}} = (A_{\text{unknown}}/A_{\text{known}}) \times \text{Concentration}_{\text{known}} \quad (1)$$

THE PERFORMANCE OF LOCALLY PRODUCED XANTHAN GUM

2.3 Moisture Content Test

Moisture content is important because xanthan gum with high moisture content tends to become lumpy when introduced into a borehole. In this study, 10 g ($W1$) of sample was measured and heated up in an oven at 110°C for 4 hours. The sample was weighted again and result was taken as $W2$. An equation of state was used to calculate the moisture content:

$$MC (\%) = [(W1 - W2)/W1] \times 100\% \quad (2)$$

2.4 Shear-thinning Determination

Multiply the dial readings (3, 6, 100, 200, 300, and 600 rpm) by 0.48 to convert from lbs/100 ft² into Pascal. The corresponding shear rates were 5.11, 10.22, 170, 341, 511, and 1022 s⁻¹. Plot the readings against the shear rates using Excel in a XY scatter plot and establish *power* trendline.

All the experimental tests were repeated for the four local xanthan gums, Flowzan, and starch. The experimental results were then compared in order to determine the best performance viscosifier.

3.0 RESULTS AND DISCUSSION

The results and discussion section were subdivided into rheological properties of local xanthan gums and comparison between Flowzan and Sample 2.

3.1 Rheological Properties of Local Xanthan Gums

Among the four local xanthan gums, the xanthan that was produced at 100°C of heat treatment (Sample 2) gave the best performance, where all the respective results were in the recommended range. The Sample 2 has the highest average viscosity of 1'24" (Table 1) at ambient temperature. But it dropped significantly to 47"56 after the hot roll process at 101.7°C (215°F). On the other hand, xanthan that produced at 110°C of heat treatment (Sample 3) gave the worst average viscosity of 42" at ambient temperature. In all cases, higher average viscosities produced greater plastic viscosities. The experimental results showed that Sample 2 was found to have given the greatest plastic viscosity of 15 cp at ambient temperature and 7 cp after hot rolling. Of the four, Sample 2 was concluded as the best performance viscosifier at ambient temperature.

Table 1 Rheological properties of local xanthan gums

Properties / mud system	1		2		3		4	
(°F)	BHR	AHR	BHR	AHR	BHR	AHR	BHR	AHR
AV (minute)	49"27	37"64	1"24	47"56	42"	39"33	53"38	41"25
PV (cP)	9	8	15	7	8	6	11	9
YP (lb/100ft ²)	23	5	35	25	13	1	27	8
GS (10"/10")	6 / 8	1 / 1	18 / 15	4 / 2	1 / 1	1 / 1	9 / 10	1 / 1
6 rpm	8	1	15	6	4	1	10	1
100 rpm	18	5	30	14	11	3	20	8
200 rpm	24	8	38	21	16	4	29	11
300 rpm	32	13	50	32	21	7	38	17
600 rpm	43	21	65	39	29	13	49	26
Moisture content (%)	17	-	11	-	15	-	13	-

Yield point is an important property of mud which dictates the ability of the mud to suspend cuttings in a borehole. Sample 2 gave an encouraging result, i.e., 35 lb/100 ft² at ambient temperature and 25 lb/100 ft² after hot roll. Three other local xanthan gums produced very low yield point especially after the hot rolling process.

Gel strength is the next crucial property needed in mud system. Again, Sample 2 was found to have given the highest gel strengths of 18/15 lb/100 ft² and 4/2 lb/100 ft² for both 10 seconds and 10 minutes before and after the hot rolling processes. Once again Sample 3 yielded the lowest gel strength with 1/1 lb/100 ft² at both before and after the hot rolling processes.

Moisture content of all four local xanthan gums was relative high if compared to the recommended range. Experimental results showed that Sample 2 gave the lowest moisture content of 11%. Sample 1 (90°C of heat treatments) gave the highest moisture content due to the duration of preparation. The reason for testing the moisture content was to ensure that mud system was lumps free during operation. Formation damage may occur if microgels formed in the wellbore. Generally, moisture content can be controlled by having a proper and dry storage system.

The unique solution properties of xanthan gum are mainly dependence on the pyruvate content which varies upon xanthan cells growth condition. The pyruvate link is existed in the four local xanthan gums, but with different concentrations. This illustrated the xanthan cells were presented in four samples with different quantities. Sample 2 gave the highest concentration of xanthan cells which was 0.198 µg/µl. This characteristic allowed Sample 2 to perform satisfactorily in a higher viscosity mud. Chromatography for Samples 1, 3, and 4 showed plenty of unknown cells growth but not xanthan cells.

All the local xanthan gum samples failed to control fluid loss at both before and after the hot rolling processes except Sample 2 that capable of reducing fluid loss, i.e. no more than 8.5 ml at ambient temperature.

Based on the experimental results, Sample 2 was found to be the best performer thus it was chosen for comparison with commercial viscosifier, Flowzan.

THE PERFORMANCE OF LOCALLY PRODUCED XANTHAN GUM

3.2 Comparison between Flowzan and Sample 2

From the experimental results shown, Sample 2 was found to be as viscous as Flowzan. Both the viscosity of Sample 2 and Flowzan decreased after they were heated up (Figure 1). The local xanthan gum showed that it could not withstand high temperature. In general, Flowzan showed marginally better results as compared to Sample 2, after being heated up to the predetermined temperatures. But still, Flowzan could not withstand high temperature especially at 101.7°C (215°F).

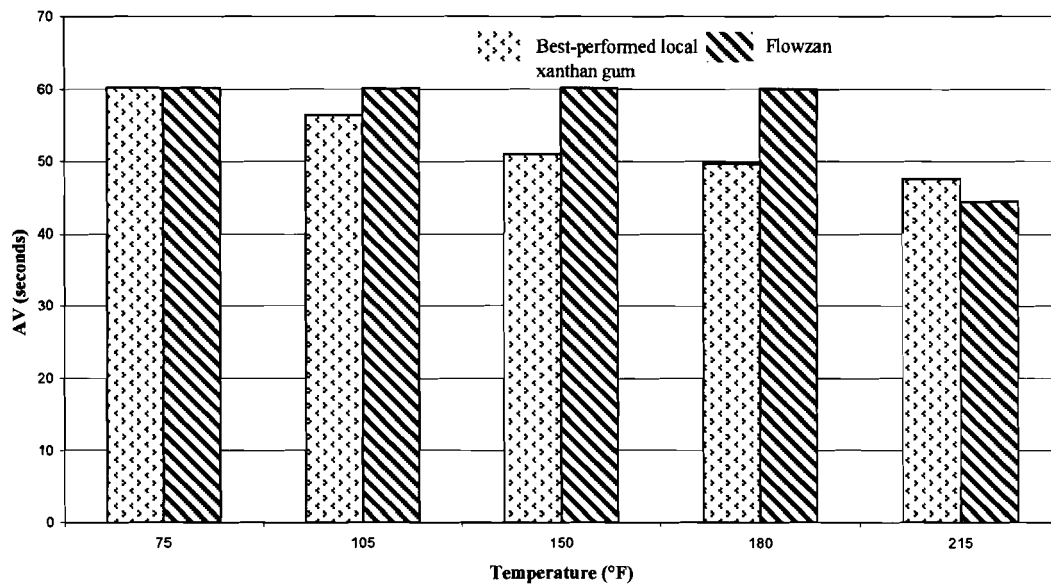


Figure 1 Average viscosity of best-performed local xanthan gum and Flowzan

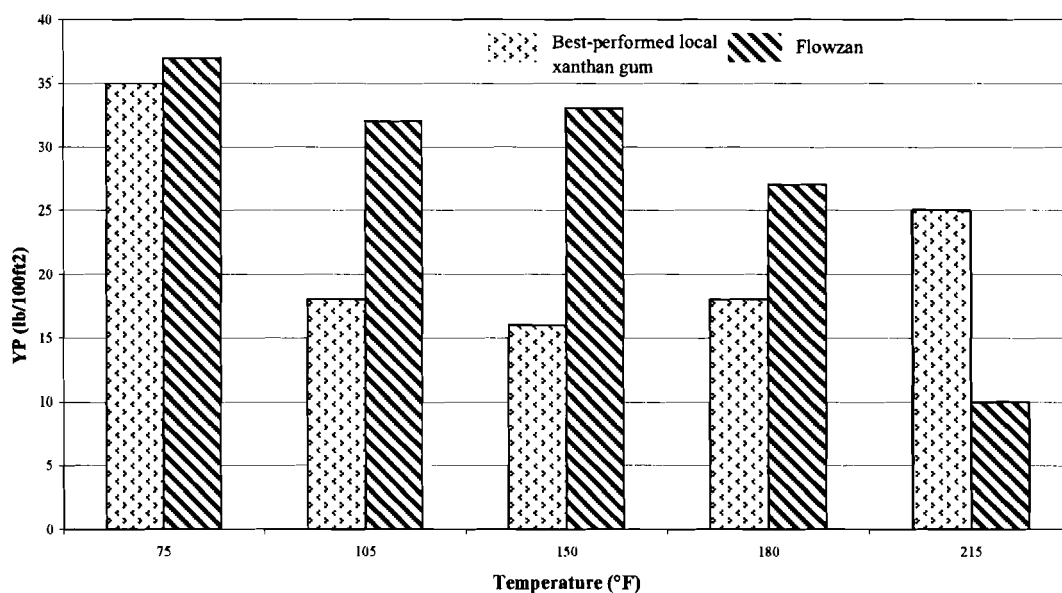


Figure 2 Yield points of best-performed local xanthan gum and Flowzan

The yield point of Sample 2 was lower than Flowzan (Figure 2). After heating the yield point of Sample 2 dropped significantly from 35 lb/100 ft² at ambient temperature to 16 lb/100 ft² at 65.6°C (150°F). However, Flowzan's yield point dropped marginally from 37 lb/100 ft² at ambient temperature to 33 lb/100 ft² at 65.6°C (150°F).

Figures 3 and 4 show the gel strength for Sample 2 and Flowzan at 10 seconds and 10 minutes, respectively. Sample 2 gave very low gel strength values once heated with 3/6 lb/100 ft² compared to Flowzan that achieved until 12/14 lb/100 ft² at the 40.6 (105°F). This explained once again that local xanthan gum could not resist high temperature, where gel strength decreased once heated up. However, Flowzan managed to withstand effect of higher temperatures of not more than 101.7°C (215°F).

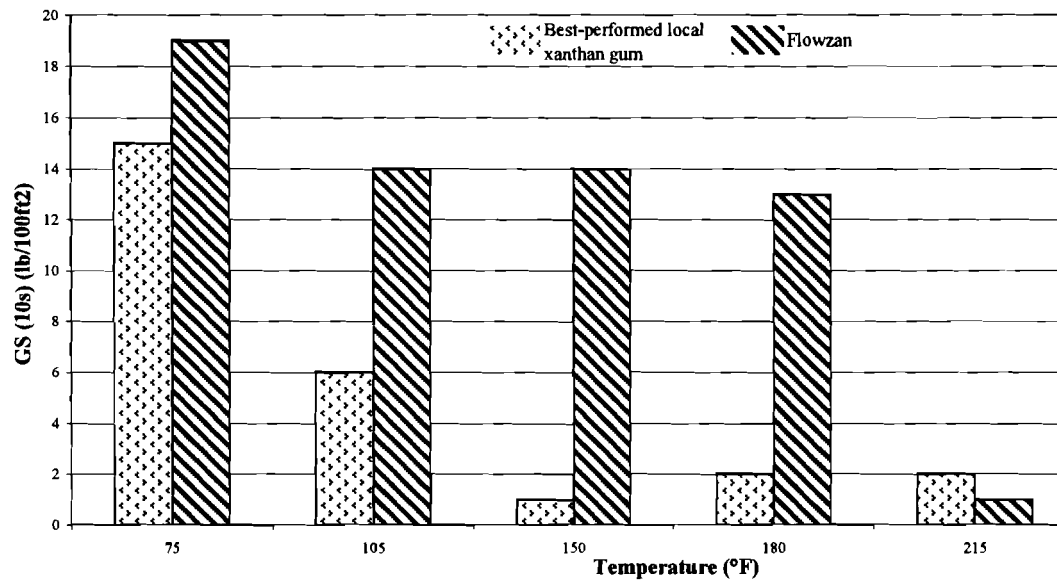


Figure 3 Gel strength (10 seconds) of best-performed local xanthan gum and Flowzan

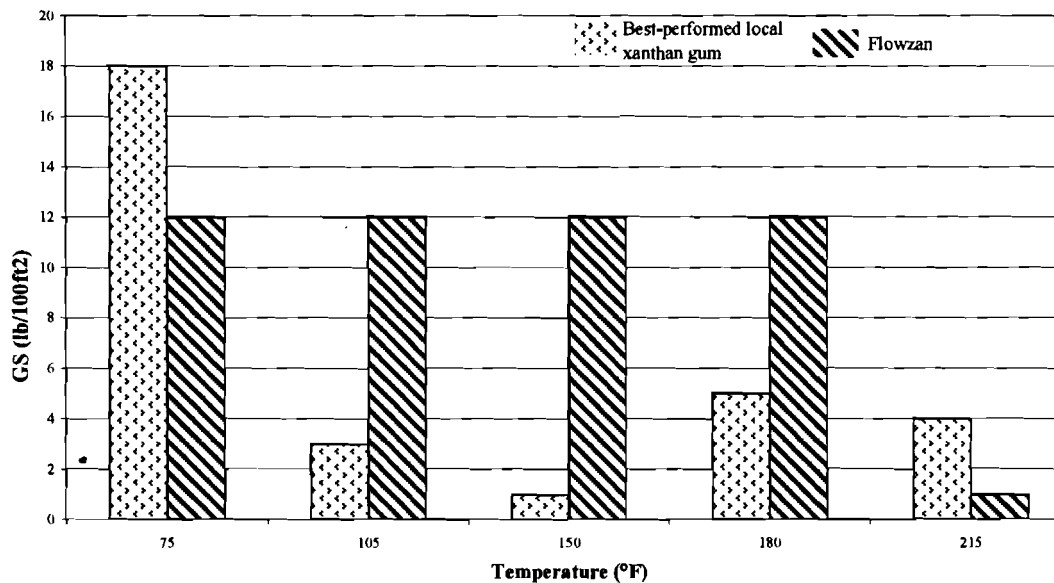


Figure 4 Gel strength (10 min) of best-performed local xanthan gum and Flowzan

THE PERFORMANCE OF LOCALLY PRODUCED XANTHAN GUM

The moisture content of Flowzan (17%) was much higher than Sample 2 (10.66%). Generally, moisture content can be controlled by having a proper and dry storage system. The Flowzan used in this experiment had relatively high moisture content because it was kept in the opened-air cupboard.

The experimental results also revealed that Sample 2 could control fluid loss effectively at ambient temperature only, i.e., experiencing 8.5 ml of fluid loss (Figure 5). After heating up to 65.6°C (150 °F), Sample 2 experienced significant fluid loss. The lower concentration of xanthan cells was the main reason of sudden increase in fluid loss for Sample 2 at temperature after 65.6°C (105°F).

On the other hand, Flowzan with higher viscosity could withstand up to 82.2°C (180°F). An initiative has been executed to compare the performance of Sample 2 and Flowzan with corn starch. It was found that corn starch could perform well at high temperatures. Generally, corn starch consists of the amylose that capable of absorbing the free-water in the mud and swells which will form *bag* that has the ability to control fluid loss.

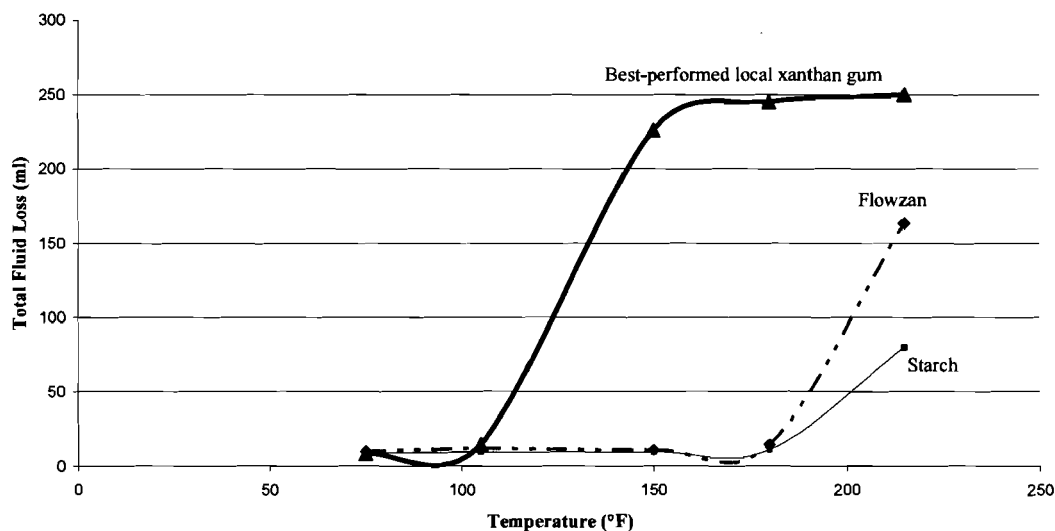


Figure 5 API fluid loss of best-performed local xanthan gum, Flowzan, and corn starch

Shear-thinning is very important where viscosity increases at low shear rates during operation especially in the overbalance pressure situation. This experiment was performed only on Flowzan and best-performed local xanthan gum because only xanthan gum could impart this unique shear-thinning rheology upon dissolution in water.

From the experimental results, both Flowzan and Sample 2 achieved the unique characteristic before hot roll. For Sample 2, at the lowest shear rate, it produced higher viscosity than Flowzan, because the concentration of xanthan cells in Sample 2 was lower than Flowzan (Figure 6).

A similar trend was achieved after hot roll where Flowzan gave better performance than Sample 2 (Figure 7). Flowzan could produce a lower viscosity at higher shear rates.

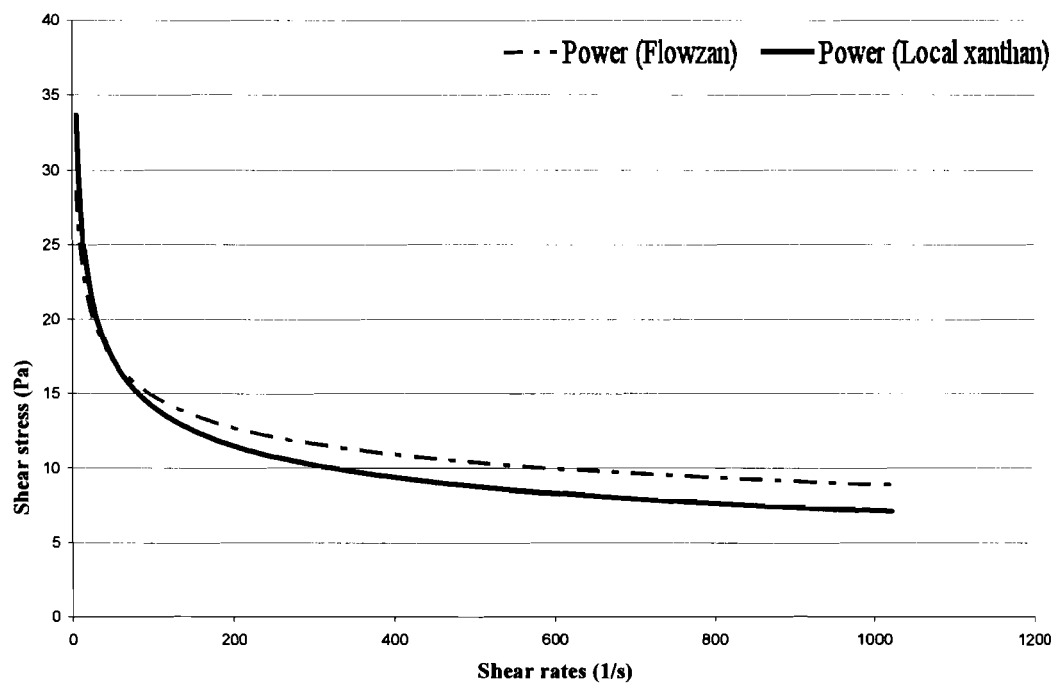


Figure 6 Shear-thinning of best-performed local xanthan gum and Flowzan at before hot rolling processes

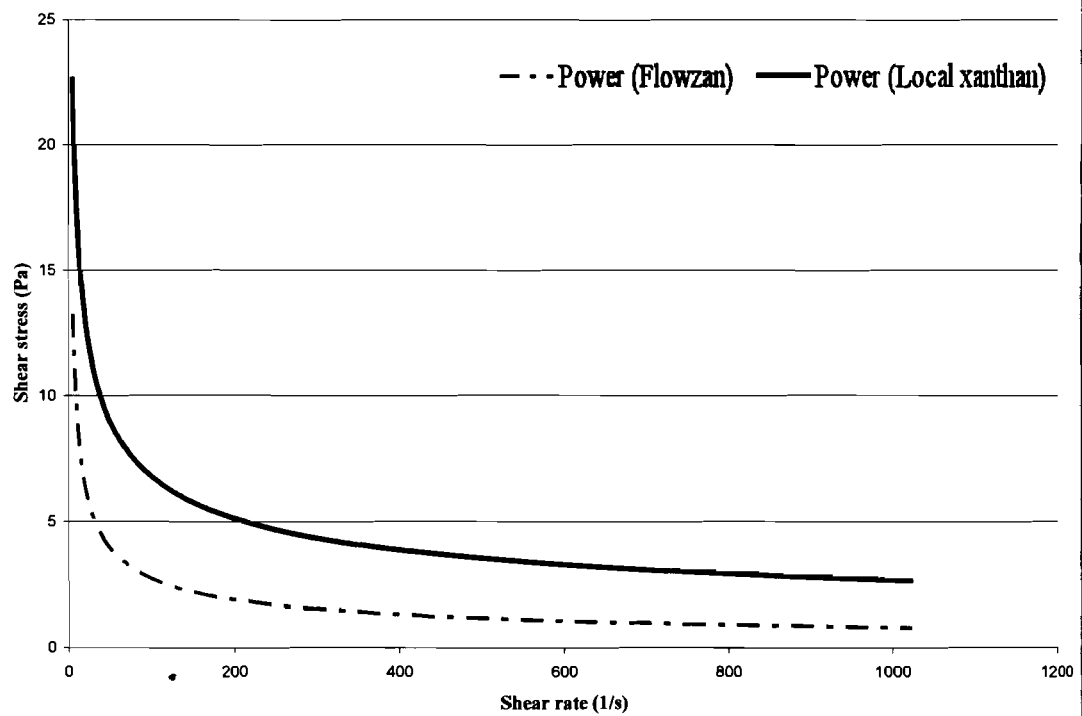


Figure 7 Shear-thinning of best-performed local xanthan gum and Flowzan at after hot rolling processes

THE PERFORMANCE OF LOCALLY PRODUCED XANTHAN GUM

4.0 CONCLUSIONS

The following conclusions were derived from the research study:

- (1) Flowzan performed better than local xanthan gum at ambient and high temperatures.
- (2) Xanthan gum produced at 100°C gave better performance compared to other xanthan gums. However, it still could not match the performance of Flowzan.
- (3) Both the xanthan gum and Flowzan could not withstand temperature of 101.7°C (215°F).
- (4) Flowzan gave better shear-thinning characteristic where it has higher viscosity at low shear rate than local xanthan.
- (5) Flowzan gave better fluid loss control up to 82.2°C (180°F) as compared to xanthan gum (Sample 2) which could perform better at temperature of not more than 40.6°C (105°F).

REFERENCES

- [1] Littman, W. 1998. *Polymer Flooding*. Amsterdam: Elsevier.
- [2] Beck, F.E., J.W. Powell, and M. Zamora. 1993. "A Clarified Xanthan Drill-in Fluid for Prudhoe Bay Horizontal Wells." *Paper SPE 25767 presented at the 1993 SPE/IADC Drilling Conference*, Amsterdam, The Netherlands, Feb. 23-25.
- [3] Heller, J.P., and M.S. Kuntamukkula. 1987. "Critical Review of the Foam Rheology Literature." *Ind. Eng. Chem. Res.* Vol. 26, No.2.
- [4] Sani, A.M., N.S. Subhash, and L. Balwin. 2001. "Experimental Investigation of Xanthan Foam Rheology." *Paper SPE 67263 presented at the 2001 SPE Production and Operations Symposium*, Oklahoma City, Oklahoma, March 24-27.
- [5] Kota Mineral & Chemical. 2000. *QA/QC Recommended Procedures*. Kuala Lumpur: Kota Mineral & Chemical.
- [6] American Petroleum Institute. 1990. *API Recommended Practice Standard Procedure for Field Testing Oil-based Drilling Fluids*. API Recommended Practice 13B-2. Dallas: American Petroleum Institute.
- [7] American Petroleum Institute. 2001. *Recommended Practice for Field Testing Water-based Drilling Fluids*. API Recommended Practice 13I/ISO 10416. Dallas: American Petroleum Institute.
- [8] Papagianni, M., S.K. Psomas, I. Batsilas, S.V. Paras, D.A. Kyriakidis, and M. Liakopoulou-Kyriakides. 2001. *Xanthan Production by Xanthomonas Campestris in Batch Cultures*. Thessaloniki, Greece: Department of Chemical Engineering, Aristotle University of Thessaloniki.